

CYCLOGENESIS ALOFT OVER SOUTHWESTERN UNITED STATES, OCTOBER 17-22, 1953

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INTRODUCTION

During the first 2 weeks of October 1953 storms entered the North American continent from the Pacific at latitudes north of 50° N. This is very clearly shown by the October storm tracks (Chart X). With the main storm centers passing rapidly eastward through Canada, only weak frontal systems were found over the United States, one of which brought significant rainfall to some sections of the Middle West and Northeast. Under these high index conditions, generally high pressures prevailed throughout the United States and the resultant weather, with the exception noted, could be termed generally fair.

As evidence of the "fair" condition prevailing over the country, the following is quoted from the *Weekly Weather and Crop Bulletin* for the week ending October 19: "Severe droughty conditions still persist over practically the entire country. . . . For the last 10 weeks the total precipitation did not exceed one-half of the normal in most of the interior and far Southwest, with less than 25 percent over much of the Ohio and middle Mississippi Valleys, most of Missouri and Iowa, in a narrow belt from southern Minnesota westward to northeastern Nevada, and in extreme southern portions of California, Arizona, and New Mexico" [1].

SYNOPTIC DEVELOPMENT

In mid-October the weather pattern began to shift from high to low index. The large dominant Aleutian Low began to split. One cell took up a position in the Kamchatka region while the other cell moved southeastward to the Gulf of Alaska.

The surface map for 0030 GMT, October 18 (fig. 1) illustrates the surface pattern during this change period. The Gulf of Alaska Low was well established, but the pattern over Canada still resembled the high index situations. The front through the central United States was very weak and had yielded only spotty precipitation.

The front on the west coast was the first of the systems under the changing regime. The 500-mb. chart, figure 2, for 0300 GMT, October 18 indicates that very cold air had already passed east of ship Papa (50° N., 145° W.). This cold air, according to reconnaissance flight reports had moved eastward south of ship Papa.

The 500-mb. prognostic chart prepared at WBAN Anal-

ysis Center from the 0300 GMT, October 18 chart (fig. 2) forecast continued eastward movement of the cold air to a Pocatello-Las Vegas-San Diego line by 1500 GMT, October 19. Some deepening was anticipated but not to the degree encountered. The constant absolute vorticity trajectory as constructed by the Wobus differential analyzer [2] was in agreement with the prognostic chart.

The jet stream at 500 mb. at 0300 GMT, October 18 was approximately along the 18,400-foot contour line. As the

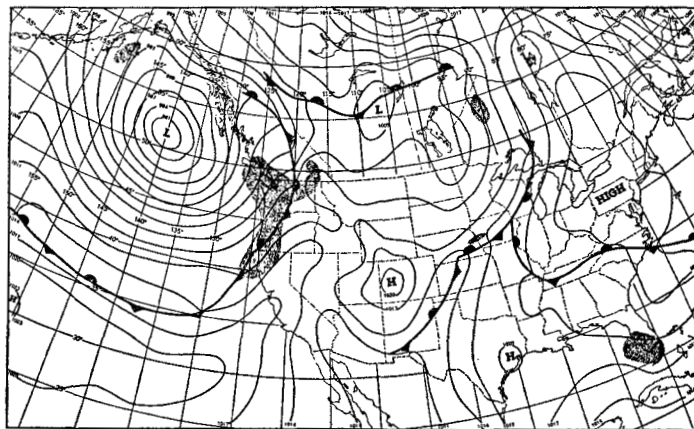


FIGURE 1.—Surface chart for 0030 GMT, October 18, 1953. Isobars (solid lines) are drawn for 3-mb. intervals.

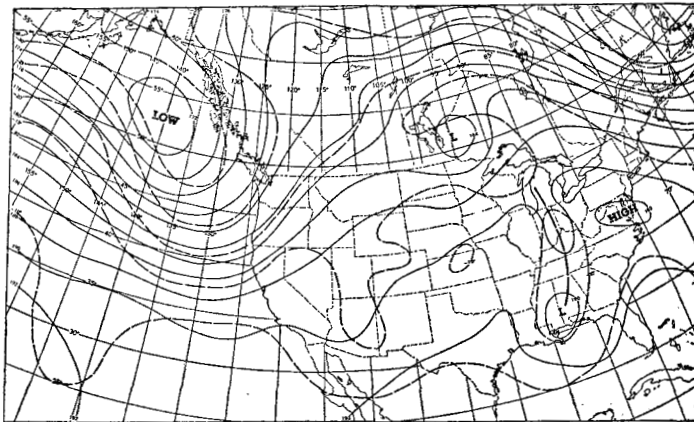


FIGURE 2.—500-mb. chart for 0300 GMT, October 18, 1953. Contours (solid lines) are drawn for 200-foot intervals. Isotherms (dashed lines) are drawn for 5° C. intervals. Positions of predominant troughs are indicated by heavy dashed lines.

jet approached the west coast it came into a divergent contour field and by Scherhag's rule, as quoted by Alaka et al. [3], "cyclones develop . . . in a delta region, i. e., a region where the upper contours diverge." The 12-hour pressure change charts at 0030 GMT, October 18 (not shown) indicated a large fall area over southwestern Canada and western United States, an area eventually associated with the cyclogenesis of the storm under discussion.

RAPID CYCLOGENESIS ALOFT

A process further adding to the development over California and Nevada was to be found upstream, over the Pacific. Along the 43d parallel, a deep wave cyclone had been moving eastward at 22 knots. Deep warm air was being transported northward ahead of the system and mid-troposphere contour heights began to rise sharply. Ship Papa's 500-mb. height rose 740 feet in the 24 hours ending

1500 GMT, October 18. By 0300 GMT, October 19 (fig. 3) this rise area had been propagated downstream and was centered at about 46° N., 135° W. The rapid ridging to the west of the deepening trough resulted in the cold air, represented by the -25° C. isotherm (figs. 2 and 3), being thrust sharply southward into Nevada.

As the cold air moved inland, surface pressures over the Pacific Northwest rose sharply and an extension of the Pacific High moved onshore. The cold surface air, topped by rising contour heights at the 500-mb. level served to maintain relatively high surface pressures over Washington and Oregon in spite of a rapidly approaching frontal system (fig. 4). One unconfirmed tornado was recorded as the cold air moved over Fowler, Colo. on the 20th.

The jet stream at 500 mb. at 0300 GMT, October 19 (fig. 3) in the vicinity of Oakland, in the southwest quadrant of the Low, progressed by 1500 GMT October 19 to near Long Beach, south-southwest of the Low as it began to curve more southeasterly. This substantiates an observation by Riehl [4] that "As long as a jet stream maximum . . . is situated or moves on the west side of an upper low, this low will not come out and it will strengthen."

To forecast the 500-mb. pattern from the chart for 0300 GMT on the 20th (fig. 5) it was necessary to note the change of the isobar-isotherm relationship that had taken place in the region just west of Annette, Alaska and Tatoosh, Wash. Strong warm air advection indicated for Tatoosh at 0300 GMT, October 19 (fig. 3) had, at 0300 GMT on the 20th (fig. 5), been replaced by cold air advection. Similar advection patterns prevailed throughout the troposphere with the reverse thermal advection above the tropopause.

That the period of cold air advection had just begun was evident from the data at hand. Between 0300

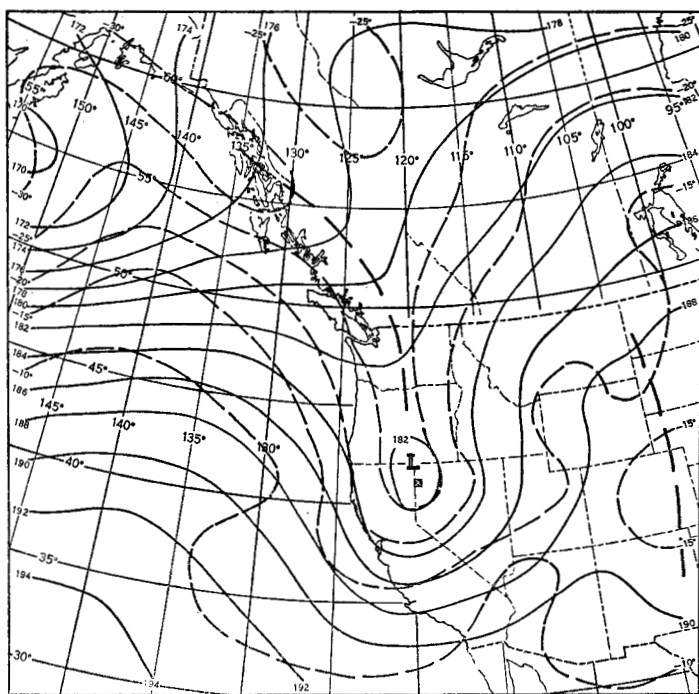


FIGURE 3.—500-mb. chart for 0300 GMT, October 19, 1953.

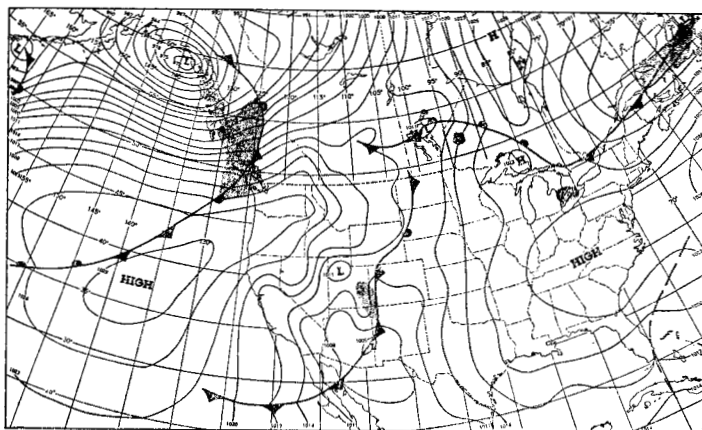


FIGURE 4.—Surface chart for 0030 GMT, October 20, 1953.

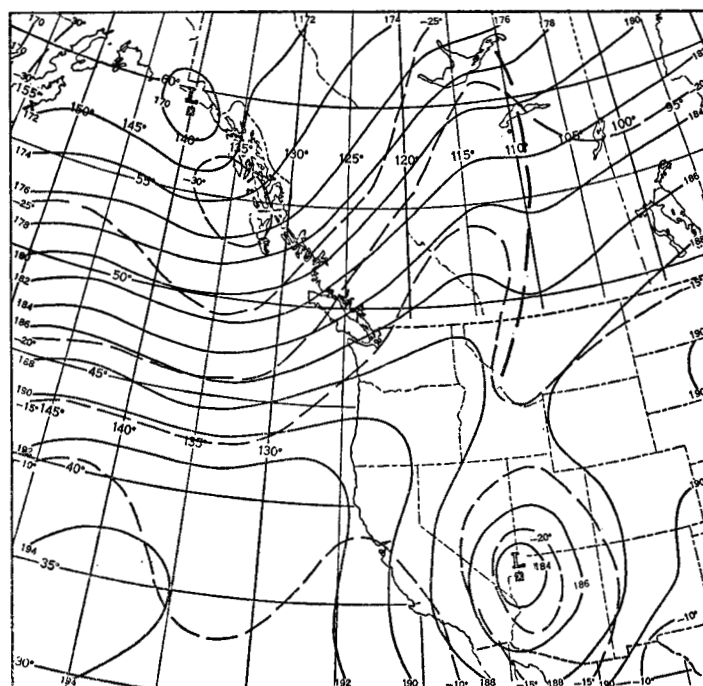


FIGURE 5.—500-mb. chart for 0300 GMT, October 20, 1953.

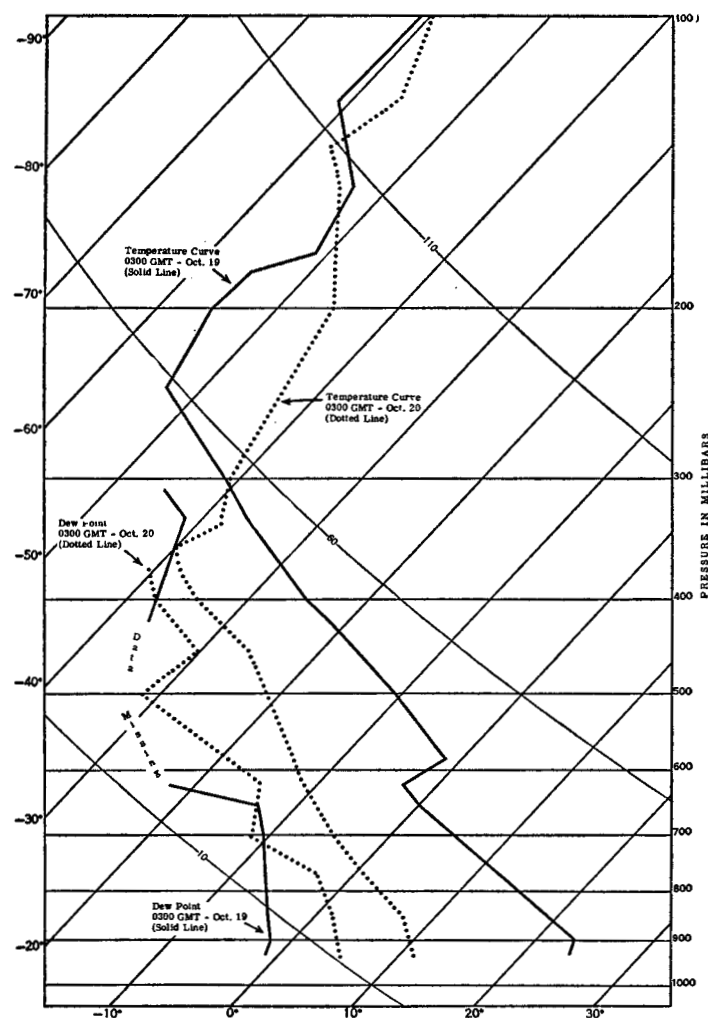


FIGURE 6.—Upper air soundings over Las Vegas, Nev. at 0300 GMT, October 19, and 0300 GMT, October 20, 1953.

and 1500 GMT, October 19, the 500-mb. temperature at Tatoosh rose from -24°C. to -13°C. By 0300 GMT, October 20 (fig. 5) the Tatoosh 500-mb. temperature had fallen to -17°C. and further cold air advection was indicated by the isotherm-isobar analysis.

Earlier discussion pointed out a shifting of the jet maximum in relation to the center of the Low near Las Vegas. The maximum at 0300 GMT on the 20th had progressed through the trough and was then in the southeast quadrant with noticeably weaker gradients to the west of the Low. Subsequent to this, the Low moved eastward, then rapidly northeastward. This bears out the second part of Riehl's [4] observation, "When the jet center has rounded the southern periphery of the low, and is not followed by another center upstream, the low will come out rapidly and weaken."

A continuity chart maintained at the WBAN Analysis Center indicates longitude 110° - 120°W. is a major trough area. With the movement of the Low near Las Vegas eastward, and with strong cold air advection in the Annette-Tatoosh region, the forecaster was confronted with a major problem as to whether the cold air would move eastward through Montana or drop southward

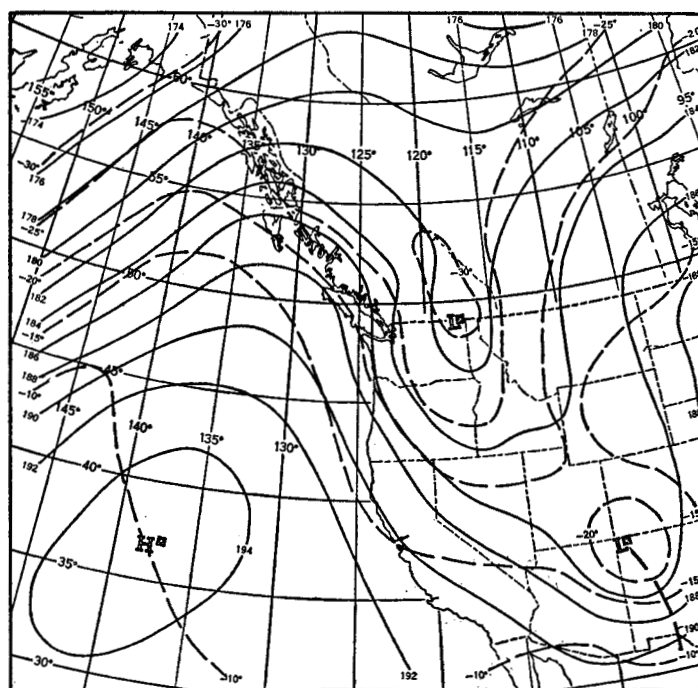


FIGURE 7.—500-mb. chart for 0300 GMT, October 21, 1953.

through Nevada as the previous surge had done. To resolve these two possibilities successfully and to prognosticate the 36-hour result would have taken, not only foresight, but courage. Note the unusual contour pattern in figure 8.

An idea of the magnitude of the cooling that had taken place with the initial surge of cold air, is obtained from the Las Vegas soundings shown in figure 6. The cooling was quite deep and uniform, with all levels below 300 mb. showing nearly 10°C. of cooling. The tropospheric cooling was accompanied by stratospheric subsidence and warming, with a tropopause at the unusually low level of 350 mb.

The warming from 300 to 150 mb., though large, was offset by slightly greater cooling in a comparable layer (600-300 mb.). The cooling below the 600-mb. level was partially nullified by the warming above the 135-mb. level, but the 24-hour result was a net sea-level rise in pressure of 9.5 mb.

A detailed analysis of the contribution of each layer will not be presented here. The reader is referred to an article by Vederman [5] for a discussion of how to make such a study.

In the 36 hours following 0300 GMT on the 20th some rather rapid changes took place in the mid-troposphere. Table 1 presents the 500-mb. temperatures and heights at a group of selected stations in the Western States. Of interest are the rapid changes at these stations. Note the succession of warming and cooling at Ely, Nev., as the first cold surge moved eastward and the second thrust down from the north. A temperature and height forecast for any of these stations would have been a taxing assignment.

Worthy of particular note is the change of flow over

TABLE 1.—500-mb. heights and temperatures at selected stations in western United States, Oct. 19–22, 1953

Date	Time	Tatoosh, Wash.		Medford, Oreg.		Santa Maria, Calif.		Boise, Idaho		Ely, Nev.		Las Vegas, Nev.		Phoenix, Ariz.	
	GMT	Feet	° C.	Feet	° C.	Feet	° C.	Feet	° C.	Feet	° C.	Feet	° C.	Feet	° C.
Oct. 19	0300	18,170	-24	18,310	-24	18,400	-13	18,360	-19	M	(-20)	18,740	-10	19,060	-10
	1500	18,610	-13	18,830	-10	18,770	-9	18,610	-17	18,400	-20	18,150	-22	18,680	-13
Oct. 20	0300	18,570	-17	19,090	-12	18,920	-9	18,810	-13	18,620	-18	18,330	-21	18,550	-20
	1500	18,280	-27	18,800	-16	19,050	-11	18,750	-15	18,710	-13	18,570	-18	M	(-19)
Oct. 21	0300	18,660	-20	18,840	-17	19,030	-13	18,280	-25	18,570	-16	18,820	-15	18,900	-12
	1500	18,960	-21	18,810	-18	18,980	-15	18,260	-27	18,240	-26	M	(-18)	18,870	-13
Oct. 22	0300	19,170	-16	18,820	-16	18,360	-17	18,530	-23	18,220	-27	18,270	-24	18,730	-17
	1500	19,170	-14	18,730	-17	18,280	-19	18,580	-21	18,320	-22	18,110	-24	18,620	-17

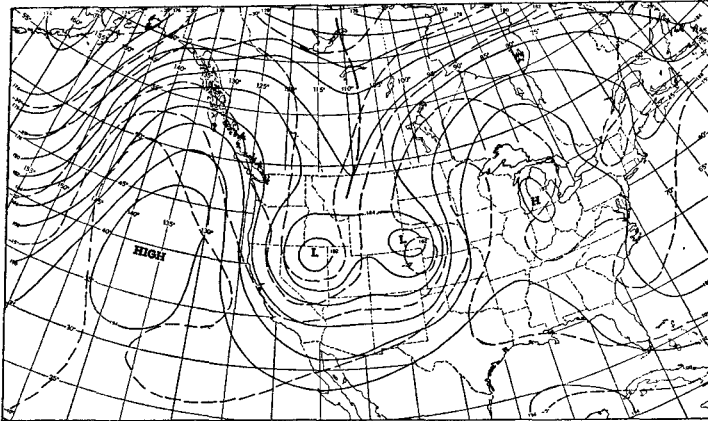


FIGURE 8.—500-mb. chart for 1500 GMT, October 21, 1953.

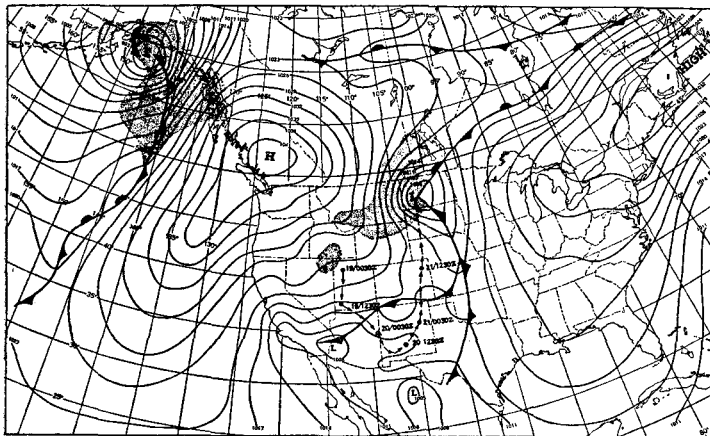


FIGURE 9.—Surface chart for 0030 GMT, October 22, 1953.

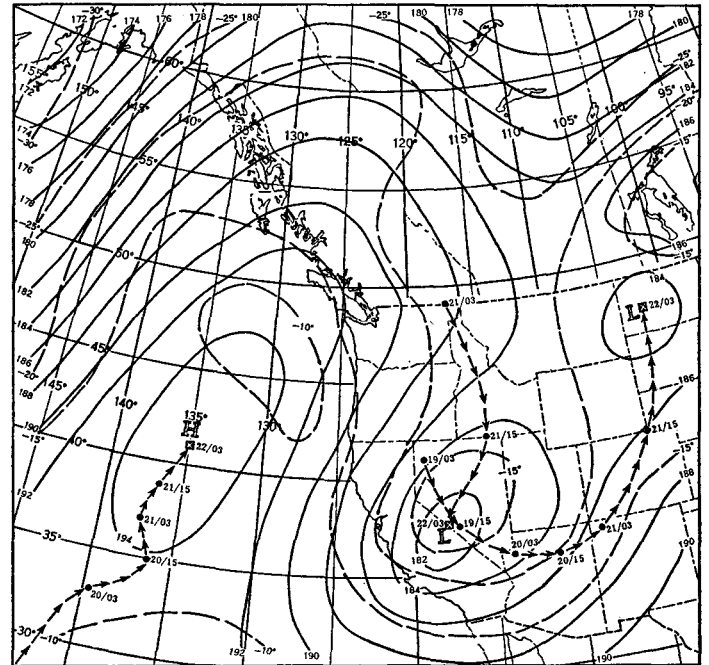


FIGURE 10.—500-mb. chart for 0300 GMT, October 22, 1953.

the Tatoosh area from 0300 GMT, October 20 (fig. 5) to 0300 GMT, October 21 (fig. 7). The southwesterly winds veered sharply as the cold air came onshore and the contour analysis indicated that stronger northerly flow had, in 24 hours, replaced the southwesterlies. The northerly flow over Tatoosh was definite up to 300 mb. and existed, although was less obvious, at the 200-mb. level. Once the northerlies were established the events following were more easily anticipated.

In line with the views expressed by Wobus and Norton [6] and employed by O'Connor and Norton [7] the strong northerly current entering northern California contributed a portion of its kinetic energy toward deepening.

On October 18 attention was directed to a deepening Low in the Pacific, and its effect upon deepening of the 500-mb. trough over Nevada. A parallel process was occurring on October 20 and 21 as a wave in the Pacific near 35° N., 160° W. began to deepen rapidly (20 mb. in the 30 hours ending 0630 GMT, October 21). Associated with the deepening was the rapid building of the Pacific High northward over ship Papa and a reorientation of the axis of the High from southwest-northeast to south-southwest-north-northeast. Its central pressure in the 30-hour period ending at 0630 GMT, October 21 rose from 1030 to 1041 mb. Figure 10 indicates that the ridge at 500 mb. just west of California moved steadily northward throughout this entire weather sequence (figs. 7, 8, and 10). With each advance northward, the ridge sharpened and flow along the west coast became more northerly.

As the 500-mb. ridge strengthened off-shore, the southward surge of cold air was facilitated. The events following 0300 GMT on the 21st occurred in rapid succession. By 1500 GMT on the 22d (fig. 8) the first Low moved from northwestern New Mexico to western Nebraska. An unusual feature of this system was that it had apparently begun to fill as it moved eastward through Arizona, but

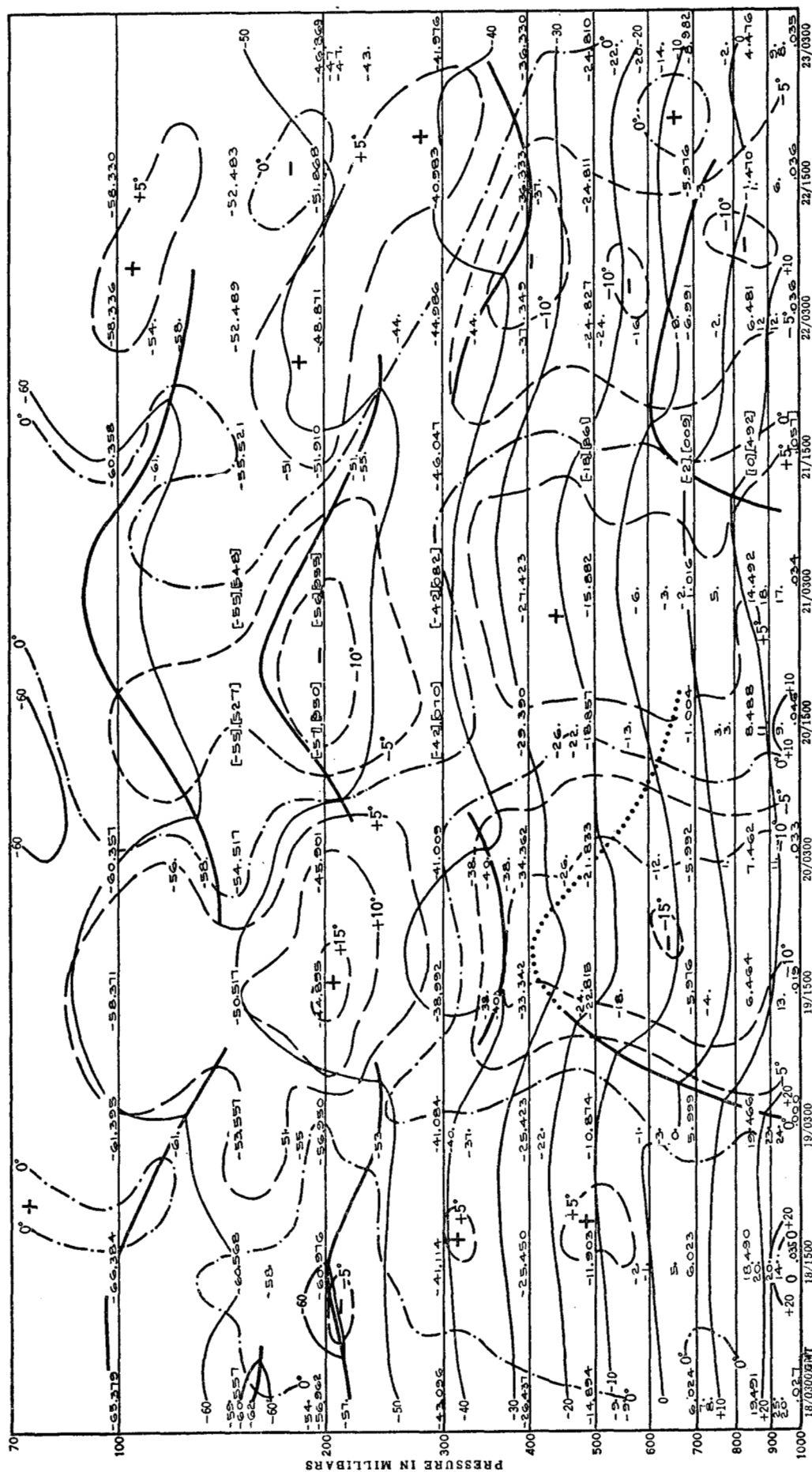


FIGURE 11.—Time cross-section for Las Vegas, Nev. from 0300 GMT, October 18 to 0300 GMT, October 23, 1953. Isotherms are light solid lines. 24-hour temperature rises are long dashes, temperature falls, short dashes, and zero temperature change lines are dot-dashed. Fronts and tropopause are heavy solid lines, heavy dotted where indistinct.

suddenly redeveloped over Colorado as warm air was drawn into the eastern and northeastern quadrants.

Simultaneously the second system plunged almost straight south and developed a closed circulation near Elko, Nev., presenting a most unusual 500-mb. pattern. Twelve hours later (fig. 10) the first Low moved to a point northwest of Bismarck, N. Dak., as the second Low moved west-southwestward to Bishop, Calif.

BREAK IN DROUGHT CONDITIONS

As the 500-mb. Low began to move northward a wave was induced on the slow moving maritime-polar front at the surface over the west central United States (fig. 9). It was by precipitation from this wave development that the drought condition east of the Rockies was alleviated.

Subsequent to the charts presented, the upper trough moved eastward as the long-wave pattern began to shift. The *Weekly Weather and Crop Bulletin* for the week ending October 26 said, "Widespread light to heavy precipitation that either ended or greatly relieved the drought situation in most areas from the Pacific States to the Mississippi Valley was the outstanding weather feature of the past week" [8].

A SUGGESTED ANALYSIS TOOL

In the preparation of the charts for this paper various attempts were made to portray the weather changes at selected points. Although several cross-sections were plotted and analyzed, none seemed to do the job particularly well. One chart that evolved from these attempts and seems worthy of presentation is figure 11, a novel attempt to show the changes that occurred over Las Vegas, Nev. An analysis of the time changes was prepared by plotting all radiosonde and pibal data for Las Vegas for the period being studied. Fronts were located by constant pressure surface, and checks of radiosonde compatibility were performed. Once an acceptable analysis was achieved and isotherms prepared, the isotherm pattern was shifted 24 hours to the right and graphical subtraction performed. Isopleths of 24-hour temperature change were then available for the atmosphere at any fixed time over Las Vegas.

An examination of the atmosphere over Las Vegas at 1500 GMT on the 19th indicates that strong 24-hour temperature changes had occurred throughout the entire air column up to 100 mb. The level of no temperature change is just below the 300-mb. level. The 24-hour thickness

change of the 1000 to 300-mb. layer was a thinning of 1060 feet, while the 300 to 100-mb. layer increased 1090 feet. Thus the cooling through seven-tenths of the atmosphere was more than nullified by warming in the two-tenths immediately above it. The 24-hour temperature change isopleths vividly point out the levels of warming and cooling.

Noticeable is the closeness of the zero change line to the 300-mb. level and the closeness of centers of the maximum change to the 200- and 500-mb. levels. Perhaps this is an indication that the secret to better forecasts lies in the correct integration of the 200-mb., 500-mb., and sea-level surfaces.

It is thought that a cross-section of this type prepared for such key stations as ship Papa might aid in getting a better picture of changes occurring.

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